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Lecture	CS326 Agent Based Modelling & Simulation (G2)
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CS426 Assignment 2

Model 1

ASSUMPTIONS

1. The room is assumed to be a square and no other obstacles except the surrounding walls.
   * This is crucial for the strategies to ensure the room is cleaned given enough ticks (vacuum cleaner know the room is a square).
   * This assumption is reasonably made as the instructions require initialization of a world that stretches from (-20,-20) to (20,20) and there is no need to change the size of the world. Additionally, there is no requirements of having the capability to allow an observer to introduce additional obstacles except the surrounding walls that is being set initially.

**** PSEUDO CODE OF EACH STRATEGY***

Strategy 1 – Swipe

```
procedure swipe-strategy
    if vacuum-cleaner is not at the bottom left corner then
        call move-to-bottom-left
    else
        ##### routing strategy #####
        ask vacuum-cleaner
            if the patch infront is not wall then
                move forward
            elseif facing west then
                turn right
                move forward
                turn right
            elseif facing east then
                turn left
                move forward
                turn left
            endif
    endif
end-procedure
```

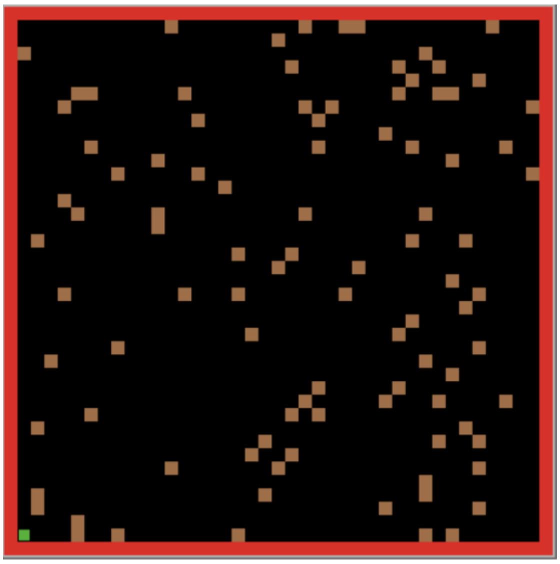


Figure 1.1

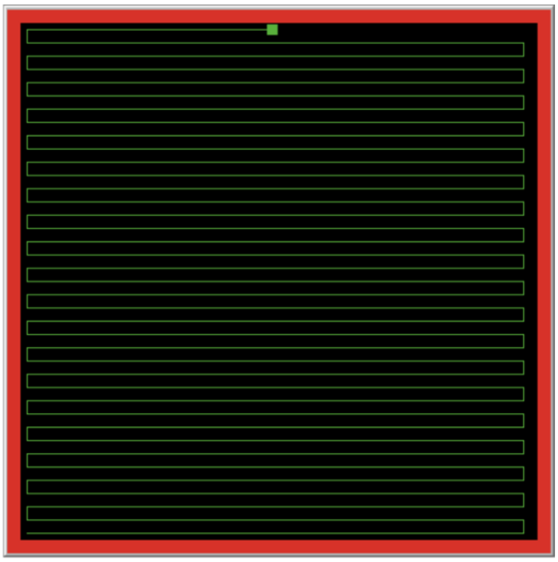


Figure 1.2

* move-to-bottom-left is a helper procedure that is called when vacuum-cleaner is not at the bottom left (see Figure 1.1), which will instruct the vacuum cleaner to move to patch -19 -19 and set its direction to east.
* Figure 1.2 shows the routing pattern of Strategy 1.

Strategy 2 – Diffuse

```
procedure diffuse-strategy
    if vacuum-cleaner is not at the bottom left corner then
        call move-to-bottom-left
    else
        if vacuum cleaner is not at the starting position then
            call move-to-starting-pos
        else
            ##### routing strategy #####
            ask vacuum-cleaner
                if odd iteration then
                    turn right
                    turn right
                    forward
                    turn right
                    forward
                else
                    turn left
                    turn left
                    forward
                    turn left
                    forward
                end-if
            end-if
    end-if
end-procedure
```

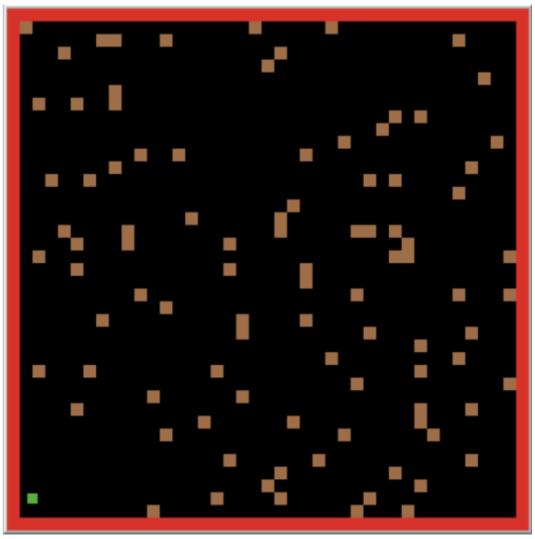


Figure 2.1

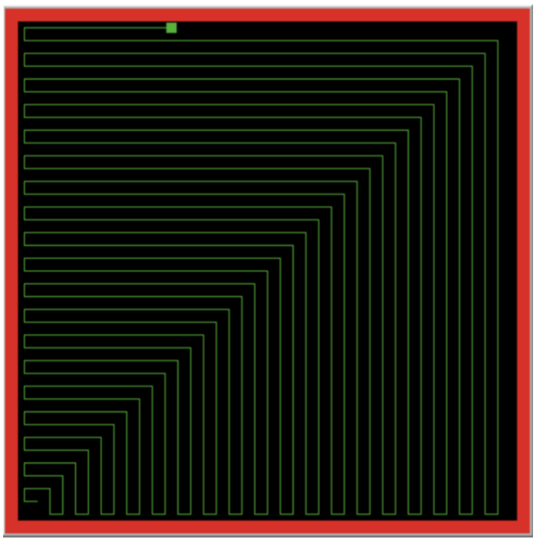


Figure 2.2

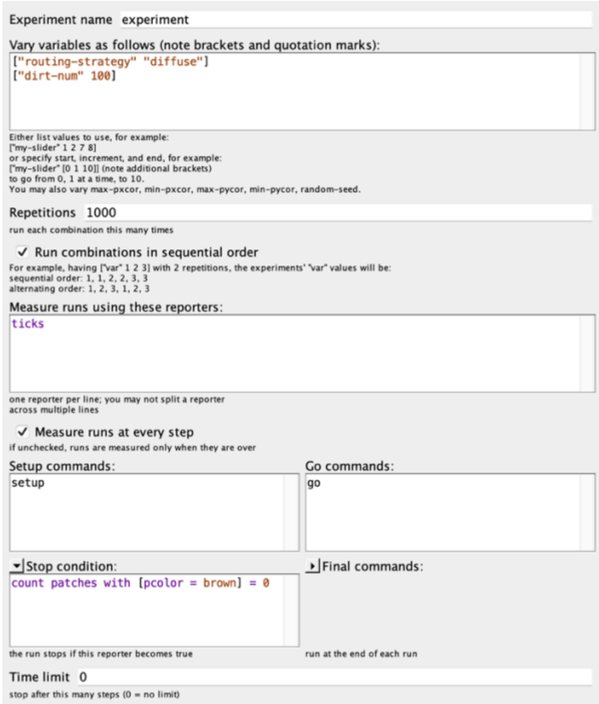
* move-to-bottom-left is a helper procedure that is called when vacuum-cleaner is not at the bottom left (see Figure 1.1), which will instruct the vacuum cleaner to move to patch -19 -19 and set its direction to east.
* move-to-starting-pos is a helper procedure that is called when vacuum-cleaner is not at the starting position of Strategy 2 (see Figure 2.1). This will instruct the vacuum cleaner to move to patch -18 -18 and set its direction to west.
* Figure 2.2 shows the routing pattern of Strategy 2.

*Note that the pseudo code is designed before the actual implementation. To avoid complexity, the pseudo code focuses on designing the routing of the strategy and does not show the integration of both strategies (which is trivial after the strategies are being designed) under a single Netlogo model. For more information, please refer to the "Code" Tab of cskang.2020_model1.

*** ARGUE THAT THE ROBOT WILL ALWAYS CLEAN THE ROOM GIVEN SUFFICIENT TIME***

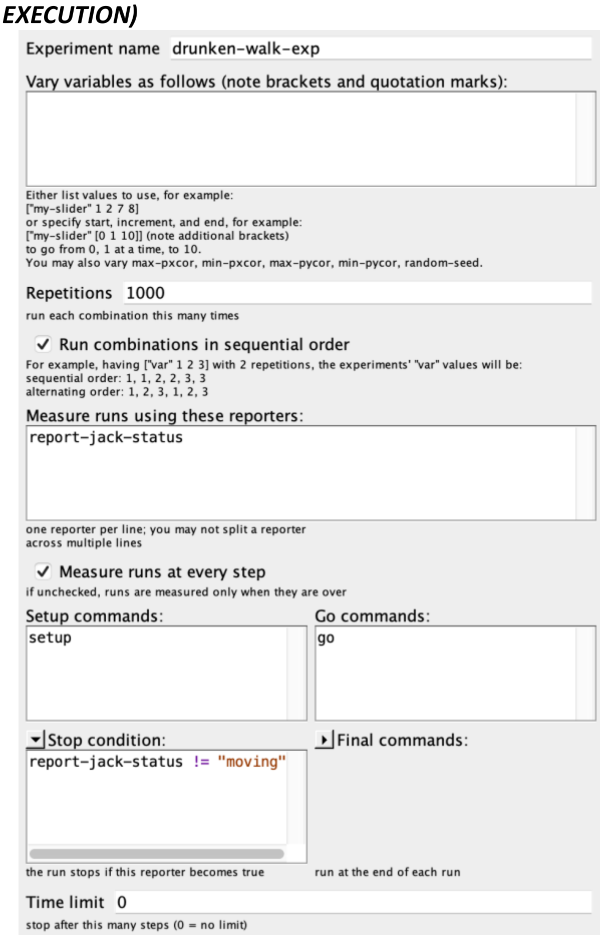
1. In order to ensure that the vacuum cleaner will always clean the room given sufficient time, it must traverse through every single patch at least once to check if any dirt exist on that patch.
2. Both strategies have O(n) time complexity to complete the task, which takes as little tick as possible because both of them traverse through each patch at most twice, and over 90 percent of the time only once.
3. Based on Figure 1.2 and Figure 2.2, it is trivial that the vacuum cleaner will clean all the dirts given enough ticks.

*** EXPERIMENT SETUP (1000 TIMES EXECUTION)***

<table>
<tr><th>Strategy 1 – Swipe Setup</th><th>Strategy 2 – Diffuse Setup</th></tr>
<tr><td>
</td>
<td>
</td></tr>
<tr><td>Average number of ticks required to clean the room with 100 dirts: 3127</td><td>Average number of ticks required to clean the room with 100 dirts: 3239</td></tr>
<tr><td colspan="2">Conclusion
- Based on the result of 1000 times execution, “Strategy 1 – Swipe” performs better than “Strategy 2 – Diffuse Setup”.</td></tr>
</table>

Model 2

*** EXPERIMENT SETUP (1000 TIMES EXECUTION)***



**** CONCLUDE THE PERCENTAGE OF CASES WHERE JACK WOULD END UP IN ANY OF THE THREE STATES***

1. Based on the result of 1000 times execution, we have the following statistics:
   * Number of times Jack ends up in ocean : ***498 times***
   * Number of times Jack ends up reaching hotel : ***295 times***
   * Number of times Jack ends up collapse : ***207 times***

2. The percentage of cases where Jack would end up in any of the three states:

State	Percentage
Ocean	(498 / (1000)) * 100 = ***49.8%***
Hotel	(295 / (1000)) * 100 = ***29.5 %***
Collapse	(207 / (1000)) * 100 = ***20.7 %***

Model 3-1

ASSUMPTIONS

1. The intrinsic value of a subject is set based on one of the following distributions (can be set through chooser) :
   a. Uniform
   b. Normal (with mean of 15 and standard deviation of 2)
   * Both distributions have lower bound of 1 and upper bound of 30.

2. The monitor "Average Number Of Links" is computed with the formula: **Total Number Of Links / Total Ticks**
   * This captures the performance of each model over ticks.

3. A hub choose its action (create/strengthen a link) based on the expected utility of each action.

**** JUSTIFICATION OF PARAMETER SETTING FOR "REASONABLE OUTCOMES"***

1. For the model to be meaningful, the parameters should be set to reasonable values to ensure successful execution of both "Greedy" and "Balance" strategies.
   * Since probability are introduced, actions performed (create/strengthen) on the link are not deterministic.
   * The rationale of the setting of model parameters is largely based on ensuring a relatively "stable execution" of strategies.
   * The mentioned term "stable execution" means any given strategy would be able to execute for at least 10,000 ticks for 85% of the time.

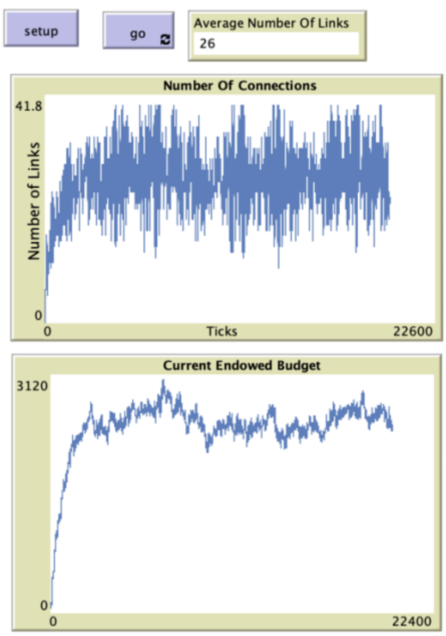
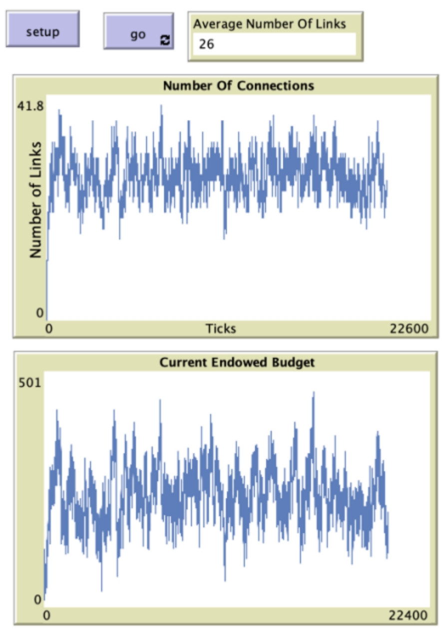
2. The table below shows the summary of parameters setting and corresponding justifications:

Model Parameter		Value	Justification
initial-budget	-	120	The initial budget is set to 120 (a relatively large value): 1. Ensure a hub has sufficient budget to establish (or strengthen) throughout the model execution. 2. Ensure the survival of established links (especially at the early phase) as to take into consideration of failure in strengthening links, which causes links to perish and budget of a hub to drop to zero over ticks.
subs-num	-	40	The number of subjects is set to 40: 1. Ensure a hub has a sufficient number of subjects to interact with throughout the model execution.
create-link-cost	A	12	The cost of link creation is set to 12: 1. Ensure the link creation is reasonable, yet affordable by a hub, i.e., 10% of initial budget. 2. Ensure the value is relatively greater than the cost of link strengthening, as in general establishing a new link should cost more than strengthen an existing link. * In this case, the cost of link creation is 150% of the cost of link strengthening.
create-link-succ-prob	B	0.80	The probability of successfully establishing a link is set to 0.80: 1. Ensure the model is realistic. * Setting the probability to a higher value (e.g., > 0.90) defeats the purpose of introducing randomness, making the model less robust. * Not setting the probability to a lower value (e.g., < 0.70) because in this case, a power center should probably focus on improving it as the successful rate is too low, which often leads to the result of running out of budget. * Note that 0.80 is computed through 0.70 + ((0.90 – 0.70) / 2)
link-initial-strength	C	35	The initial strength of an established link is set to 35: 1. Ensure a link to survive a reasonable number of ticks even without strengthening it. * This is especially crucial for early phase of the model execution. * This implies that a link will survive through 70 ticks (link-initial-strength / link-strength-decay -rate) even without a single strengthening action. * "70 ticks" is a reasonable as there are sufficient number of subjects to avoid exhaustion (a hub has no subjects to establish links with). Also, as mentioned in **1.**, we wish to have a "stable execution" of model across different strategies.

link-strength-decay-rate	D	0.5	The decay rate of link strength is set to 0.5 units per tick for any link: 1. Ensure a link does not perish too soon, otherwise a hub would be too busy with strengthening the existing links instead of creating new ones. * Note that although the goal of a hub is to maximize the influence by establishing links, it should balance its choice of actions. If the links perish in very few ticks, the hub would have no choice but to keep establishing a new connection with subjects.
strengthen-link-cost	E	8	The cost of link strengthening is set to 8 to: 1. Ensure the link strengthening is reasonable, yet affordable by a hub, i.e., 6.7% of initial budget. 2. Ensure the value is relatively smaller than the cost of link creation, as in general establishing a new link should NOT cost more than strengthen an existing link.
strengthen-link-succ-prob	F	0.85	The probability of successfully strengthening a link is set to 0.85: 1. Ensure the model is realistic. * Refer to "create-link-succ-prob" parameter for the similar reasoning. 2. Ensure the value is relatively greater than the probability of successfully creating a link, as in general establishing a new link is more "difficult" than strengthening an existing link.
link-strengthen-val	G	15	The increase in strength of a strengthened link is set to 15: 1. Ensure the strengthening itself is meaningful, i.e., a strengthened link should be able to last a reasonable number of ticks (link-strengthen-val /link-strength-decay-rate = 30 ticks) before the next strengthening takes place. 2. Ensure the value is relatively smaller than initial strength of a link, as we defined link creation to be more costly (relative to link strengthening), it is reasonable to have part of this additional cost contributes to the extra strength of a fresh link.
link-max-strength	H	50	The maximum strength of a link is set to 50: 1. Ensure this value (50) is greater than initial strength of the links (35) in order to be reasonable. 2. Ensure the value is NOT unreasonably large as it plays a role in computing the probability of a reward. The larger this value is, the smaller the probability of reward is: Probability Of Reward = (I + (h / H) (1 - I)) * Assuming I and h are fixed, increasing H decreases the overall value.
reward-prob-factor	I	0.85	The factor (I) that used in computing the probability of a reward is set to 0.85: 1. Ensure the model is realistic. * One major reason of link creation and strengthening is to maximize "influence" so that a hub has "good relationship" with other subjects and may be beneficial from this relationship. This "benefit" can be modelled as reward in this case. A hub is reward-driven to create and maintain its links.
strategy	-	-	A chooser introduced for user to choose a designed strategy.
Intrinsic-val-dist	-	-	A chooser introduced for user to choose the underlying distribution of generation of intrinsic value for each subject.

**** THE DIFFERENCE & PERFORMANCE BASED ON THE IDENTIFIED PARAMETERS***

The chart below shows the execution of 2 strategies for 20,000 ticks:

<table>
<tr><th>Strategy 1 – "Balance"</th><th>Strategy 2 – "Greedy"</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td colspan="2">Comparisons On The Difference Of Performance</td></tr>
<tr><td colspan="2">Average Number of Links
- Both strategies performs equally well, having an average of 26 links/tick. This implies that given sufficient number of ticks, on overall both strategies will give roughly same number of links.</td></tr>
</table>

Number of Connections
- Based on the pattern of the plot, we can clearly see that Strategy 1 has a relatively greater spread of number of connection across ticks, high number of created links perish after sometimes and high number of new links get created. For Strategy 2, the spread is smaller, which implies at any given tick, a hub using Strategy 2 is more likely to give a number of links closer to its average number of links, whereas Strategy 1 is more likely to have the number of links greater or smaller than its average.
- Depending on the scenario, Strategy 1 performs better when the spread is insignificant as long as the total number of links are relatively high, otherwise Strategy 2, which is more "stable" performs better.

Current Endowed Budget
- Based on the pattern of the plot, we can clearly see that a hub that employs Strategy 1 has its budget being several times of the that of a hub that employs Strategy 2 over the long run.
- Strategy 2 has a few ticks which the current endowed budget is low, which could lead to 0 budget and all links perish.
- Given that both strategies give the same average number of links, it is reasonable to have Strategy 1 being the winner under this metric.

Conclusion
- The is a trade-off between "stability" in terms of number of links and "budget".
- If a hub wishes to be cost-effective, having good overall number of links, and reduce the risk of having 0 budget, then Strategy 1 is preferred.
- If a hub wishes to have relatively high number of links for most of the time, and is willing to pay for the incurred cost, then Strategy 2 is preferred.

Model 3-2

ASSUMPTIONS

1. All the parameters remained unchanged, except the link-strength-decay-rate is set to 2.0 instead of 0.5.
    * The reason is that reward is not randomly generated through uniform distribution anymore, but through relative strength.
    * Increasing the link-strength-decay-rate helps to prevent the exhaustion of subjects for link establishments.

**** EVALUATE THE TWO-CENTER SCENARIO USING THE TWO STRATEGIES IN TASK 1***

1. Competition is introduced to the model (reward is computed based on the relative strength), the hub with higher link strength connected to a common subject will get the higher portion of reward.
2. This implies hub with stronger links are more likely to survive and get stronger over ticks, and vice versa.

**** "GAME" FORMULATION***

1. To formulate this competition as a game, we need the following essential elements:

Players	**Two Players** - Hub 0 - Hub 1
Strategies	**Two Strategies** - Strategies 1: Balance - Strategies 2: Greedy
Payoffs	* Refer to the next section – "Construction Of Payoff Matrix"
Information	**Complete Information for both hubs**

2. Assume all players are rational.

**** CONSTRUCTION OF PAYOFF MATRIX***

		Hub 1	
		Balance	Greedy
Hub 0	Balance	***(9, 9)***	***(9, 14)***
	Greedy	***(14, 9)***	***(14, 14)***

* Refer to excel sheets under model 3 for corresponding computations
1. The values are derived from the average number of links of each strategy across 100 executions, each with 10,000 ticks.

**** COMPUTATION OF NASH EQUILIBRIUM***

Based on the payoff matrix, the Nash Equilibrium is (14,14) with both hubs choosing Greedy strategy, as no player can unilaterally improve his own payoff.

**** EVALUATE & ANALYZE THE PERFORMANCE***

1. When both strategies are the same, both hubs will have same number of links.

** However, if both hubs choose Balance, they will have relatively lower number of links as compared to the case where both choose Greedy.*
** This is reasonable as Balance prioritizes balancing the actions, which causes it more likely to spend its budget maintaining the existing links, whereas Greedy will try to establish links when its budget permits, hence the latter case is likely to have more number of links when competition is introduced.*

2. When two different strategies are used, Greedy is the winner.

**** COMPARE THE PERFORMANCE OF STRATEGIES BETWEEN TWO-CENTER & ONE-CENTER SCENARIO***

1. Greedy performs better in terms of maximizing the number of links, unlike what is observed in Task 1, both strategies have similar performance.
2. This phenomenon could imply that Greedy is more competitive and therefore, be the first who establish the links. Then, it enjoys the benefits of having more rewards due to both more concurrent links with relatively higher link strength. This agrees with what has mentioned earlier, stronger hub will get stronger overtime.

End of Assignment 2